Advanced Pipe Technology Study

EXECUTIVE SUMMARY REPORT

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IN COOPERATION WITH

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FOREWORD

The Advanced Pipe Technology Project was accomplished as part of the Ship Producibility Program, under management by Bath Iron Works Corporation. The Ship Producibility Program is part of the National Shipbuilding Research Program originally defined by the Ship Production Committee of the Society of Naval Architects and Marine Engineers. The project was funded jointly by the Maritime Administration and the U. S. shipbuilding industry, and was accomplished by Newport News Shipbuilding under a subcontract agreement with Bath Iron Works Corporation with assistance from a group consisting of industry consultants and members of the Advanced Pipe Technology Advisory Committee. This group represented all disciplines of piping design/engineering, fabrication, assembly/installation, and related activities.

The Advanced Pipe Technology Project generated a very high level of Interest and involvement among the many industry consultants contacted during the course of project development. This interest and involvement was perhaps due to the general realization within the U. S. shipbuilding industry that foreign shipyards are improving their competitive edge by expending much research and development effort to reduce outfitting costs of their ships via the application of computer-aided design practices and the acquisition of automated production equipment. considering that the cost of outfitting a typical commercial ship in a domestic shipyard is 30-40 percent of total ship cost, it is understandable that the U. S. shipbuilding industry is seeing the need for more cost-effective methods of outfitting.

EXECUTIVE SUMMARY

The purpose of the Advanced Pipe Technology Project was to document the present domestic and foreign state-of-the-art methods in marine piping technology, to identify and evaluate particularly cost-effective methods within that technology, and to establish an atmosphere of mutually beneficial cooperation among shipbuilders, design agents, regulatory bodies, research organizations, and marine suppliers in order to solve common problems relative to piping technology. The project was accomplished by a research team from Newport News Shipbuilding with assistance from many domestic and foreign industry consultants. The end products of the project are this Executive Summary Report, a Summary Final Report, a Detailed Final Report, and a Backup Data Report, all of which were prepared utilizing a common basic format to facilitate cross-referencing.

The project was essentially a study of the mechanics of utilizing raw materials, equipment, and human resources to produce finished ship piping systems, and covered state-of-the-art methods related to piping design/engineering, piping fabrication, and piping assembly/installation.

The most significant findings relative to piping design/engineering are:

- The foreign shipyard practice of promoting the sale of ships developed from standard in-house design offers a significant competitive advantage of such shipyards over domestic shipyards, which rarely build more than three ships of a type and which generally must develop (or work through a design agent to develop) an essentially new contract definition for each ship type.

- The capability to produce completely computer-generated diagrams, such as is being developed by the Italcantieri shipyard, offers the ultimate in cost-saving potential in the preparation of piping diagrams.

- The extensive use of isometric sketches in lieu of conventional three-view orthographic arrangement drawings and the development of these sketches directly from scale models at the Odense shipyard is a significant finding since this practice eliminates much of the duplicative effort seen in domestic model-building design/engineering practices.

equipment to both cut and end-prep the bulk of their piping.

- The most advanced domestic equipment available for cold bending is the numerically-controlled 2D booster bending machines produced by Teledyne Pines and the 1.5D and 2D booster bending machines produced by Conrac Corporation.

  The most advanced domestic welding equipment available is the semi-automatic orbital welder now offered by several manufacturers.

  All four foreign shipyards surveyed have recently remodeled their pipe shops to suit the installation of semi-automated assembly-line production equipment. In all cases, such equipment has been integrated with more conventional production equipment to make the overall pipe shop operation as efficient and as flexible as possible.

  Relative to pipe joining methods, the extensive use of conventional and Van-Stone type flanges in the foreign shipyards surveyed is a significant departure from domestic shipbuilding practice, which utilizes welding techniques to a high degree.

  The use of centering-pin type Dresser couplings and the use of the newly-developed nickel-titanium shape memory couplings offer perhaps the highest potential for cost reduction in the joining of pipe.

The most significant findings relative to piping assembly/installation are:

- Pre-assembly and pre-outfitting of piping systems is at a relatively low level in the domestic shipyards surveyed.

  All of the European yards have put strong emphasis and planning on pre-outfitting concepts and have a decided advantage in this area, especially in the construction of large oil tankers. The foreign shipyards surveyed have excellent facilities which have been designed especially for advanced methods of pre-assembly and pre-outfitting.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

INTRODUCTION

This project has examined in detail almost every activity that is directly involved in the overall piping process, which includes piping design/engineering, piping fabrication, and piping assembly/installation. While detailed findings are presented under the appropriate common title headings of the summary Final Report, Detailed Final Report, and Backup Data Report, this brief Summary and Conclusions section attempts to present the most significant overall findings of the project and to make some specific recommendations on the basis of certain findings.

THE PIPING PROCESS

In general, the results of this project indicate that the entire piping process cycle - from the initial design through the final test and operation of ship piping systems - must be considered before attempting to implement state-of-the-art improvements for a particular phase of the cycle. The implementation of advanced computer-aided design/engineering methods must usually be justified not only on the basis of savings in the development of design/engineering documents, but also on the basis of downstream benefits to the fabrication and assembly/installation activities. Full utilization of such computer-aided methods generally requires that more sophisticated production equipment be acquired for the pipe shop; a good example of this would be the acquisition of a numerically-controlled bending machine which would take full advantage of the ability of a computer-aided design/engineering system to produce bending instructions on numerical control tapes or punched cards.

The high cost of capital improvements to facilities and equipment generally demands that updating be evolutionary rather than revolutionary. Numerically-controlled, semi-automated piping production equipment such as now used by many foreign shipyards is economically justifiable only if a high volume of work can be expected on a relatively near-term basis. Domestic shipyards, usually building only up to a few ships of a class on an intermittent basis, cannot usually generate enough near-term investment capital to justify the acquisition of such equipment, especially when the cost of implementing a computer-aided design/engineering supporting software system is considered. The domestic governmental policy of directly subsidizing the construction of ships rather than directly subsidizing the improvement of the shipbuilding process itself in order to reduce domestic/foreign cost differentials has also been a deterring

factor in the modernization of the domestic shipbuilding industry. However, world competition, the lack of and cost of highly-skilled labor, and tight delivery Schedules, all demand that the methods presently utilized in the overall piping process be continually upgraded. The results of this project indicate strongly that success in the world market depends heavily upon the ability to design and produce piping systems in a short period of time and with a high degree of efficiency.

The timely and efficient design and production of ship piping systems in domestic shipyards is presently hampered by many serious problems, the most important of which are:

- Lack of communication on a continuing basis among the various segments of the shipbuilding industry relative to improved methods and techniques in the piping process.

- Industry-wide redundancy in the research and development and the practical evaluation of new methods relative to the piping process.

- Imposition of costly practices and slow approval cycles of governing regulatory bodies.

- Ship production schedules which do not allow sufficient time for the finalization of piping design/engineering documents prior to the commencement of outfitting.

- Inadequate or outdated facilities and equipment which make impossible the implementation of cost-effective piping fabrication methods.

- Limited piping assembly/installation facilities, equipment, and space, which preclude full utilization of cost-effective pre-assembly and pre-outfitting methods.

- Continuing material procurement problems and use of non-standard components which raise the cost of any proposed computer-aided design and cause dimensional problems during installation.

For foreign shipyards, existing governmental policies have made such problems practically non-existent. Direct governmental financial support of foreign shipyards also puts domestic shipyards at a disadvantage. It therefore appears that improvements to the domestic shipbuilding industry must continue . to depend heavily upon government assistance in order to

make the overall level of piping technology competitive in the world market.

Summary data and conclusions relative to the piping design/engineering process, the piping fabrication process, and the piping assembly/installation process are presented below under appropriate separate title headings. In some cases, specific recommendations have also been presented.

THE PIPING DESIGN/ENGINEERING PROCESS

INTRODUCTION

Execution of the piping design/engineering process in a timely, orderly, efficient, and comprehensive manner is absolutely essential if costs relative to the overall ship outfitting process are to be kept to a minimum. This is especially true if the construction of the ship must commence prior to the completion of detailed design work, as is very often the case in domestic shipyards. Since the execution of the piping fabrication and assembly/installation processes is done in accordance with issued detailed design/engineering documents, delays in providing these documents or errors within them can have a tremendous impact on fabrication and assembly/installation costs. For example, the cost of correcting a single shipboard interference due to a design error can easily be double that of installing the same components without an interference problem.

Capabilities for piping design/engineering range from almost total dependence of some domestic shipyards upon design agents to total in-house computer-aided design/engineering capabilities of many foreign shipyards. From a study of the current trade literature and of the documentation of the on-site surveys of the four foreign shipyards conducted for this project, it can be concluded that there is a very strong trend among foreign shipyards toward the maximum use of computers for all phases of the piping design/engineering process (including basic contract definition), and that the role of the design agent in this process is minimal. In contrast, the role of the design agent, while somewhat diminished by the passage of the Merchant Marine Act of 1970, is still a vitally important factor in the domestic shipbuilding industry. It should be noted that because of the unique relationship of the design agents with the ship owners and shipbuilders they are in an advantageous position to promote cost-effective methods at the earliest stages of basic and detailed design; yet, because of their limited access to information on the capabilities of individual shipyards, they tend to perpetuate “standard practice”, even when such practice may not be the most cost-effective choice.

Because of the necessary present dependence upon design agents, limited investment capital, and the lack of a single reliable source of continuously updated information relative to piping design and engineering, domestic shipyards are, in general, lagging far behind their foreign competitors in the development of comprehensive computer-aided design/engineering systems. Perhaps the most important recommendation that can be made as a result of the Advanced Piping Technology Project is that a permanently funded MarAd Piping Design/Engineering Research Group be established to develop computer-aided design/engineering systems and to continuously update domestic shipyards on improved methods of piping fabrication and assembly/installation. Such a research group could also serve to keep mutually beneficial lines of communications open among all segments of the shipbuilding industry. Costs incurred by MarAd in maintaining such a group would most likely be recovered many times over via reduction of ship costs relative to the piping process.

For the purposes of discussing specific findings, the piping design/engineering process is conveniently divided into the following definable phases:

- Contract Definition Phase
- Piping Schedule and Special Material Identification Phase
- Piping Diagram Phase
- Piping Arrangement Phase
- Pipe Detail Phase
- Ancillary Phases
- Revision Phase

A brief summary and related conclusions and recommendatio are presented for each of these phases in the following paragraphs.

CONTRACT DEFINITION PHASE

In general, domestic shipyards rely far more heavily upon design agents for the basic design of ships they build than do the foreign shipyards: in fact, the four foreign shipyards surveyed specifically for this project seldom rely on the use of design agents. The policy of the foreign shipyards appears to be to concentrate on the total in-house development of so-called

"standard designs" which meet existing world market demands and which can be modified somewhat to suit the needs of individual owners.

The foreign shipyard practice of promoting the sale of ships developed from standard in-house designs offers a significant competitive advantage of such shipyards over domestic shipyards, which rarely build more than three ships of a type and which generally must develop (or work through a design agent to develop) an essentially new contract definition for each ship type. The foreign shipyards surveyed not only reduce the time required for the total design/engineering effort but also are able to dramatically reduce the time required for actual production of the ship via the use of standardized flow-line and pre-fabrication techniques. Although there is some loss of flexibility in providing specific owner requirements, this does not appear to be a significant disadvantage.

SCHEDULE AND SPECIAL MATERIAL/EQUIPMENT IDENTIFICATION PHASE

The development of realistic piping design/engineering schedules and the early identification of special material/ equipment requiring long lead-time procurement are important factors in keeping costs relative to the overall piping process at a minimum. Operating under more compressed schedules than their foreign competitors, domestic shipyards generally pay a high price for consequent design errors and work stoppages due to late material.

In contrast, the standard ship design concept and the material procurement policies of the foreign shipyards surveyed allows them greater flexibility than domestic shipyards in the establishment of piping design/engineering schedules and in the scheduling of in-yard dates for special materials required for ship piping systems. This flexibility appears to be partly responsible for the success of foreign shipyards in maintaining a high level of efficiency in their production line fabrication and pre-outfitting assembly/ installation activities.

PIPING DIAGRAM PHASE

The fundamental nature of the piping diagram phase of work makes dramatic cost reductions difficult. The use of various computer programs for pipe sizing and related calculations and the use of pre-printed structural backgrounds in the preparation of piping diagrams are the most significant cost-effective methods observed at the domestic shipyards and design agent offices surveyed for this project. However, it appears that the capability to produce completely computer-generated

diagrams, such as is being developed by the Italcantieri shipyard, for example, offers the ultimate in cost-saving potential in the preparation of piping diagrams. While the use of computer-generated diagrams is greatly facilitated via the standard ship design concept utilized at Italcantieri, it appears that the use of such diagrams in the less standard operating environment of domestic shipyards also offers significant cost-saving potential.

Since the research and development of computer-generated diagrams was outside the scope of this project, it is recommended that a study be funded to determine applicability and cost-saving potential for domestic shipyards. If cost-saving potential is indicated, such a study should also include the development of the basic computer program and user's manual, and a listing of hardware requirements to implement the method (It is probable that such a method could be easily implemented with existing computer facilities available to most domestic design agents and shipyards).

PIPING ARRANGEMENT PHASE

The practices utilized to accomplish the piping arrangement phase of work vary rather widely among the facilities surveyed. Each facility has had to adopt practices to suit local conditions, such as the availability of competent designers and design facilities, union restrictions, etc.

of the two types of layouts used for piping arrangements - orthographic and isometric - the orthographic is by far the most widely used. However, the use of isometric layouts, observed at Sun Shipbuilding and Dry Dock Company and Odense Steel Shipyard, Ltd., appears to offer significant advantages over orthographic layouts for certain applications. The extensive use of isometric sketches in lieu of conventional three-view orthographic arrangement drawings and the development of these sketches directly from scale models at the Odense shipyard is a significant finding since this practice eliminates much of the duplicative effort seen in domestic model-building design/engineering practices.

The use of models and mockups, although inherently one of the best visual methods of interference control, is quite limited for use in the shipbuilding industry, primarily because of the long-lead time, special facilities, and skilled personnel that are required for their production. Most shipyards and design agents surveyed have therefore adopted the space composite as the primary interference control method. The Avondale system of preparing piping arrangement layouts directly from

space composite reproducibles is one of the most significant findings relative to this phase of work. The use of pre-printed structural backgrounds, and machine-lettered piping arrangement lists/tables are also significant findings.

PIPE DETAIL PHASE

The pipe detail drawing is the vital interface document between the piping design/engineering activity and the piping fabrication activity. Accurate graphic portrayal of pipe pieces and complete and accurate information required for the fabrication are important factors in keeping piping fabrication costs at a minimum.

The development of computer-aided pip detail programs is one of the most significant advancements in the field of marine piping technology, for it is the most practical first step toward the development of comprehensive piping design/ engineering systems. Although present computer-aided pipe detail programs are not yet cost-effective for the piping design/engineering activities they are cost-effective for the fabrication activities since pipe detail output sheets provide more accurate and more complete data for the production of piping assemblies and for the efficient loading of pipe shop facilities. The ability to efficiently load the pipe shop facilities is one of the most critical factors to consider in setting up automated or semi-automated pipe shop equipment.

ANCILLARY PHASES

Ancillary phases of the piping design/engineering process generally include the preparation of documents related to pipe hangers and operating gear, the preparation of various supporting lists/schedules, and the preparation of technical documentation for ship piping systems.

In general, it can be concluded that most shipyards surveyed have standardized their procedures for pipe hangers and operating gear design, and for the preparation of various supporting lists/schedules and test procedures. The primary difference between the procedures utilized by domestic and foreign shipyards is that the foreign shipyards maximize the use of computer methods in the preparation of these documents.

REVISION PHASE

The process of making revisions is inherently costly, especially if revisions affect components already fabricated or even assembled and installed on the ship. The domestic shipyards surveyed which are able to allow more time to thoroughly

review design/engineering documents before issuing them have far fewer revision problems than do the other shipyards surveyed. The foreign shipyards surveyed, capitalizing once again on their standard ship designs and their material procurement policies, appear to have the least problems of all shipyards surveyed.

MATERIAL AVAILABILI AND SELECTION, MATERIAL ESTIMATING,AND MATERIAL PROCUREMENT

Common to all phases of the piping design/engineering process are the activities related to the selection, estimating, and procurement of material required for the fabrication and assembly/installation of ship piping systems. Problems related to these activities are particularly severe for domestic shipyards.

Limited availability and high cost of marire piping components have forced most domestic shipbuilders to develop alternate methods of fabrication, the use of which must be integrated into the design/engineering process. Some of these methods reduce the number of total components that would otherwise be required for the fabrication of a typical piping system, thus simplifying the process of material estimating. Material estimating in foreign shipyards is an easier process than in domestic shipyards, since foreign shipyards build more ships of any given type and generally have more detailed design documents to use for material estimating. Foreign shipyards also have the advantage in the procurement of materials since they generally buy materials on a continuing contract basis from vendors.

INTEGRATED PIPING DESIGN/ENGINEERING PROCESSES OR SYSTEMS

All of the foreign shipyards surveyed are in the process of developing comprehensive computer-aided piping design/engineering systems. Except for the Odense Shipyard, the ultimate objective in the development of these systems is the automatic routing of interference-free piping runs in machinery spaces and the automatic generation of all documents required for the orderly and timely fabrication and assembly/installation of ship piping system. For the Odense Shipyard, the ultimate objective is the automatic generation of these documents utilizing information lifted directly off scale models.

● Several comprehensive Japanese systems, such as the Mitsui MAPS System, the IHI CADS System, and the Hitachi-Zosen Hicass-P System, have been developed to provide supporting software for related automated piping production systems.

The most advanced domestic computer-aided piping design/engineering systems are the Computer-Aided Design and Manufacturing System (CAPDAMS) of Newport News Shipbuilding, and the Computer-Aided Piping Design and Construction (CAPDAC) System of the Naval Ship Research and Development Center. CAPDAMS is presently capable of computer-generating complete pipe details, including sketches and material/fabrication instructions; the CAPDAC system is presently addressing the problem of generating drawings via interactive graphics techniques. Both of these systems are intended eventually to facilitate the development of nearly all documents required in the piping process.

THE PIPING FABRICATION PROCESS

INTRODUCTION

The piping fabrication process involves a variety of end products manufactured from ferrous, non-ferrous, fiberglass, and plastic pipe and components. The facilities required are as varied as the products, since equipment must be provided to fabricate and handle a size range from one-half inch to forty-eight inches in diameter and from several inches to twenty feet or more in length. This variety of materials and sizes is also compounded by various wall thicknesses, odd configurations of bent pipe, and assemblies and modules which can weigh in excess of forty tons.

For the purposes of discussing specific findings, the piping fabrication process is conveniently divided into the following definable phases:

- Materials Handling/Storing Phase
- Pipe and Component Marking/Tagging Phase
- Pipe Cutting/End-Preparation Phase
- Pipe Bending Phase
- Pipe Joining Phase
- Pipe Cleaning/Coating Phase
- Ancillary Phases

A brief summary and related conclusions and some recommendations are presented for each of these phases in the following paragraphs. Findings relative to pipe shop layouts are also presented.

PIPE SHOP LAYOUTS

In general, the foreign pipe shops surveyed have all recently been arranged and modernized to maximize the use of assembly-line production techniques. While this has greatly improved the efficiency of their piping fabrication process, it has also reduced overall flexibility. In comparison, the domestic pipe shops surveyed have all been arranged over the years to suit slowly changing needs and local conditions, which has led to inefficient pipe shop layouts and the acquisition of incompatible equipment. The domestic pipe shops surveyed are, however, far more flexible than the foreign pipe shops surveyed.

MATERIAL HANDLING/STORING PHASE

The handling/storing of pipe and components is an important area for economic consideration. Shop throughput is enhanced if handling is minimized and storage of components and tools is convenient to area of usage. The pipe shop handling/storing practices of domestic shipyards are geared to the need for a high degree of flexibility. Although flexible, domestic pipe shop storage areas and crane capacities are, in general, limiting factors in the construction of large piping assemblies; therefore, little prefabrication is accomplished in the pipe shops. In contrast, the pipe shop handling/storing practices of foreign shipyards are geared to assembly-line production of piping for limited ship types. Although more efficient, such handling/storing practices are far less flexible than those seen in domestic shipyards.

PIPE AND COMPONENT MARKING/TAGGING PHASE

In general, the proper marking and tagging of pipe and components during the fabrication process is one of the most important activities in the pipe shop. Pipe and component marking/tagging is, however, largely a matter of local preference at each of the domestic and foreign shipyards surveyed; no single method appears to be significantly better or more cost-effective than another. The only innovative practice uncovered in this area is the ingenious match-marking technique developed by Electric Boat Division for pre-orientation of fittings.

PIPE CUTTING/END-PREPARATION/FORMING PHASE

The pipe cutting/end-preparation/forming phase of the piping fabrication process is the first phase of work in the actual transformation of raw materials into finished piping assemblies. It is vitally important, therefore, that this phase of work be executed with care and accuracy in order to

avoid the proliferation of errors throughout the piping fabrication process. The most advanced equipment seen in domestic shipyards for pipe cutoff and end-preparation is the pipe lathe which can handle a variety of pipe sizes and materials. The foreign shipyards surveyed rely on their semi-automated production equipment to both cut and end-prep the bulk of their piping. The most significant findings relative to pipe forming techniques were seen in the domestic shipyards which use such techniques to offset the high cost of fittings. The swaging of pipe ends to eliminate pipe couplings, and the extrusion of bosses on pipe to eliminate pipe tees are typical examples. The foreign shipyards surveyed use Van-Stone flanges extensively but only one domestic shipyard surveyed was found to use such flanges.

PIPE BENDING PHASE

The pipe bending phase is the most expensive phase of work in the piping fabrication process. Considerable capital investment is reauired to set up and use even the smallest and simplest of bending equipment. This fact has forced the smaller domestic shipyards to fabricate all but the smallest of piping with purchased elbows.

The two basic processes of bending are cold bending and hot bending. The most advanced domestic equipment available for cold bending is the numerically-controlled 2D booster bending machines produced by Teledyne Pines and the 1.5D and 2D booster bending machines produced by Conrac Corporation. Only two domestic shipyards - Newport News Shipbuilding and Avondale Shipyards, Inc. - have been able to justify the use of 2D bends on commercial contracts; the high cost of the special bending machines required has prohibited other yards from using 2D bends. The most common bend radii are therefore 3D and 5D, made on conventional bending machines. Most shipyards surveyed cannot cold-bend pipe over 6 inches (1.P.S.) in diameter and, therefore, must either hot-bend such pipe or fabricate with elbows. The most advanced domestic hot bending equipment has been developed by the Crippen Pipe Fabrication Corporation, which offers subcontract services to the shipbuilding industry at a reasonable cost.

PIPE JOINING PHASE

Relative to pipe joining, the extensive use of conventional and Van-Stone type flanges in the foreign shipyards surveyed is a significant departure from domestic shipbuilding practice, which utilizes welding techniques to a high degree. The development of Van-Stone flanging machines has made the use of such flanges more attractive, but as yet has not made

a significant impact on the domestic shipbuilding industry. The extensive use of centering-pin type Dresser couplings in foreign shipyards is also a significant departure from domestic shipbuilding practice which generally utilizes welded clips to prevent relative movement of coupling and piping. The use of centering-pin type Dresser couplings and the use of the newly-developed nickel-titanium shape memory couplings offer perhaps the highest potential for cost reduction in the joining of pipe.

The most advanced domestic welding equipment available is the semi-automatic orbital welder now offered by several manufacturers. This equipment can produce exceptionally good welds for most pipe materials. Also, there is presently much interest in finding acceptable induction brazing equipment and it is therefore recommended that the current MarAd Pipe Joining Methods Project address this problem in detail.

PIPE CLEANING/COATING PHASE

There are no significant findings relative to pipe cleaning/coating in the domestic shipyards surveyed, except that the use of galvanized pipe is a serious problem area. It is therefore recommended that the current MarAd Pipe Materials Project address in detail the problems associated with the use of galvanized pipe and study possible alternatives.

Due to their wider use of ferrous piping, the foreign shipyards surveyed generally have much better facilities for pipe cleaning, painting, and galvanizing. The most advanced equipment for this work documented is the semi-automated chemical cleaning and shot-blasting equipment of the Kockums Shipyard.

ANCILLARY PHASES

Several shipyards surveyed have found it cost-effective to fabricate, rather than buy, certain components required for the piping fabrication process or for the piping assembly/installation process. The in-house production of gaskets, pipe caps, and pipe hangers by some shipyards is a cost-effective alternative to purchasing such items. The cost-effectiveness of this practice appears to be highly dependent upon local factors such as personnel, equipment and storage availability, volume of items required, and cost of purchased items.

INTEGRATED PIPING FABRICATION PROCESSES

All four foreign shipyards surveyed have recently remodeled their pipe shops to suit the installation of semi-automated assembly-line production equipment. In all cases,

such equipment has been integrated with more conventional production equipment to make the overall pipe shop operation as efficient and as flexible as possible. However, the present requirement of the semi-automated equipment that flanges be used in the piping fabrication process is a serious drawback of such equipment with respect to applications in the domestic shipbuilding industry, which relies heavily upon welding and brazing techniques for piping fabrication. There is some evidence, especially in the case of the German-made Oxytechnik equipment, that equipment vendors have recognized this shortcoming and are developing equipment which can handle pipe with or without flanges. The application of such equipment to domestic shipbuilding could have a dramatic cost-effective impact *on* the piping fabrication process.

THE PIPING ASSEMBLY/INSTALLATION PROCESS

INTRODUCTION

The assembly/installation of piping has as its final product, operational systems which will transport steam, air, and various other fluids which are required for ship operation and the, life support and comfort of the crew. Piping of various sizes, materials, and configurations must be installed in almost all parts of the ship, often in locations which are tight to work in, and under adverse working conditions. The assembly/installation must be accomplished such that the piping is properly aligned and joined so as to provide a leakproof and structurally sound system. Many of the types of activities required for the piping fabrication process are also required for piping installation; however, the adversity of shipboard conditions usually requires that the equipment and techniques used to perform a similar activity, such as welding, be quite different for the piping assembly/installation process.

For the purposes of discussing specific findings, the piping assembly/installation process is conveniently divided into the following definable phases:

- Materials Handling/Storing Phase
- Piping Field - Fabrication Phase
- Piping Hanging Phase
- Piping Joining Phase
- Ancillary Phase

A brief summary and related conclusions are presented for each Of these phases in the following

paragraphs. Findings relative to assembly/installation area layouts are also provided.

ASSEMBLY/INSTALLATION AREA LAYOUTS

The proper layout of piping assembly/installation areas and the physical proximity of these areas to the ship construction site are important considerations for shipyards seeking to improve the efficiency of the overall outfitting process. Such considerations are especially important when attempting to take full advantage of pre-assembly and pre-outfitting techniques. The areas set aside for the assembly/installation of piping systems in most domestic shipyards surveyed are generally small and poorly arranged with respect to total ship production. This condition severely limits the level of pre-assembly and pre-outfitting in such yards. Recognizing the merits of increased pre-assembly and pre-outfitting, most shipyards are reorganizing existing facilities to accommodate such work. In contrast, the foreign shipyards surveyed have excellent facilities which have been designed especially for advanced methods of pre-assembly and pre-outfitting.

MATERIALS HANDLING/STORING PHASE

Except for some improvements in pallet design, the domestic shipyards surveyed utilize essentially conventional methods of handling and storing raw materials and piping assemblies. Special handling/storing problems are solved on a case basis to suit existing conditions. There has been little need among domestic shipyards to develop specialized handling equipment to facilitate the assembly/installation of piping systems, such as has been the case in the foreign shipyards surveyed. The development of such equipment by the foreign shipyards has been an outgrowth of their extensive "pre-assembly and pre-outfitting methods which are geared to the production-line concept of ship construction.

PIPING FIELD-FABRICATION PHASE

The piping field-fabrication phase of the piping assembly/installation process is the first phase of work in the actual transformation of raw materials and piping assemblies into finished piping systems. Field fabrication of piping generally requires that the piping assembly/installation activity must perform, on a much smaller scale many of the functions of the piping fabrication activity in the pipe shop.

Most shipyards surveyed field-fabricate piping up to a size of 1-1/2 inches (1. P.S.) in diameter. Only for special cases do shipyards attempt to formally detail piping in this size range. Field fabrication of piping involves the same basic operations as required for shop fabrication, but to a much smaller scale. Equipment for such fabrication is characterized by portability and flexibility. In some cases, the piping assembly/installation activity may act as an in-house design agent for field-fabricated piping by preparing pipe details and then having the pipe shop actually fabricate the piping. For gage lines, the use of multi-tube gage line bundles appears to be highly cost-effective.

PIPING HANGING PHASE

The piping hanging phase is one of the most critical phases of work in the piping assembly/installation process. The proper alignment and installation of pipe hangers is very often essential for proper system operation. All shipyards surveyed follow essentially the same procedure for the hanging of piping assemblies. The only significant problems noted were the usual access problems and the special problems associated with the handling of large piping assemblies in the machinery spaces of large ships. These problems are less severe in foreign shipyards where much piping is preassembled into various packages or pre-outfitted into hull blocks or panel sections.

PIPING JOINING PHASE

The integrity and serviceability of a ship piping system are dependent upon having strong leak-proof joints which tie the system together. The foreign shipyards surveyed prefer the use of flanged joints, which are compatible with their pipe shop production methods and their pre-assembly and pre-outfitting techniques. The domestic shipyards surveyed have traditionally preferred the use of welded or brazed joints and have therefore encouraged the development of advanced equipment, such as semi-automated orbital welders, which facilitates the onboard joining of piping.

ANCILLARY PHASES

Certain ancillary phases of work must usually be accomplished before piping systems can be considered finished and ready for in-service operation. Such ancillary phases include the cleaning and coating or insulating of the external surfaces of piping, internal flushing and the testing and operation of the piping systems. The external cleaning, coating, and insulating of piping systems are important ancillary

phases of work which are generally difficult to accomplish in the onboard outfitting environment of most domestic shipyards. The ancillary phases of internal flushing, and testing/operation of piping systems are also difficult to accomplish for the same reason. The most significant finding relative to domestic practices is the use of flushing rigs and diagrams which greatly speed up the onboard flushing of certain systems. The foreign shipyards surveyed have the advantage in all of these phases since they are able to accomplish much work in the pre-outfitted hull block and panel sections, under the ideal conditions of their pre-outfitting shops.

INTEGRATED PIPING ASSEMBLY/INSTALLATION PROCESSES

Integrated piping assembly/installation processes include all those activities related to pre-assembly and pre-outfitting. All of the foreign yards have put strong emphasis and planning on pre-outfitting concepts and have an advantage in this area, especially in the construction of large oil tankers. There is a decided difference in pre-outfitting under shop conditions between the domestic and foreign shipyards surveyed. In the foreign shipyards, great emphasis is placed on modular assembly of deck piping for tankers, for extensive pre-outfitting of machinery spaces, and even for bringing structures to covered areas for purposes of installing pipe off the ship. This concept is carried to the installation of gage lines and instrumentation. The advantages include:

- less material handling and damage;
- less lost time and productivity due to inclement weather;
- “reduced staging requirements:
- reduced congestion and noise on ship;
- improved working conditions;
- improved supervision:
- improved control of material and equipment.

piping sub-assemblies, made in the shop, or under shop conditions, for installation in modules, ship subassemblies, or on board ship, appear to be highly cost-effective. (The Kockums Shipyard, for example, indicated a 2000 man-hour savings for a 700 ton machinery space unit) .

The foreign shipyards, for the most part, are so laid out that there is adequate space provided for storage of raw and in-process material, and for performing piping assembly/ installation with adequate space for product and equipment. Flow is usually straight-line with little or no backtracking or extra handling.